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ABSTRACT

This research project studied the effects of hierarchical versus heterarchical hypermedia structures of Web-based case representations on complex problem-solving skills and knowledge assembly in problem-centered learning environments in order to develop a system or model that informs the design of Web-based cases for ill-structured problems across multiple disciplines. Two groups of college students (n=3 and n=3) were assigned to work through an ill-structured problem, represented hierarchically and heterarchically in a Web-based format. A Web-based tracking program was deployed to track students' journeys through the hypermedia case designs. Students were observed while interacting with the problem and were interviewed after submitting their case solutions. Results from the tracking program, observations, case solutions, and interview questions address case design issues, problem-solving issues, and group processes. Findings reveal that heterarchical case designs potentially increase student collaboration in a Web-based hypermedia design of an ill-structured problem and engage students in thinking critically about case content. (Contains 3 tables, 2 figures, and 34 references.) (Author/SLD)

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Abstract

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Assessing Complex Problem-Solving Skills and Knowledge Assembly Using Web-Based Hypermedia Design

Research Problem

Several research projects and studies (Booth-Sweeney, 2001; Herreid & Schiller, 2001; Siegel, et al., Spiro, 2000; Rogers & Erickson, 1998; Gerdes, 1998; Sutyak, et al., 1998; Fitzgerald & Semrau, 1996; Jacobson, et al., 1996) have investigated the use of cases or problems in instruction particularly in relation to case structure (e.g. linear versus hypertext, narrative versus conceptual) and problem complexity (e.g. well-defined versus ill-structured), and the impact of such variables on advanced knowledge acquisition. However to date, there is no explicit framework or instructional model to guide the design of Web-based hypermedia cases, particularly for ill-structured problems or learning tasks that require students to engage in complex problem-solving and knowledge transfer. In addition, Grissom and Koschmann (1995) contend that cases or problems that are used as a stimulus for authentic activity are hard to come by in disciplines other than medicine, business, and law, and suggest that hypertext/hypermedia may be a more efficient and effective medium to produce cases for learning environments that are problem-centered.

This research project studied the effects of different hypermedia structures of Web-based case representations on complex problem-solving skills and knowledge assembly in problem-centered learning environments in order to develop a system or model that informs the design of Web-based cases for ill-structured problems across multiple disciplines. Ill-structured problems are the kinds of problems or tasks that are encountered in everyday practice requiring the integration of several content domains and possessing multiple solutions or solution paths (Jonassen, 1997). They are problems that are "situated in and emergent from a specific context"

(Jonassen, 1997, p. 68) and "lacking solutions that are indisputably correct" (Kagan, 1993, p.715). Therefore they are arguably most appropriate for engaging students in authentic activity and assessing complex problem-solving skills and knowledge transfer.

Theoretical Framework

Duffy and Cunningham (1996) identified five strategies for using problems in instruction: (1) the problem as an example; (2) the problem as an integrator or test; (3) the problem as a guide; (4) the problem as a vehicle for process; and (5) the problem as a stimulus for authentic activity. This research project focused on their strategy of using *the problem as a stimulus for authentic activity*. Authentic activity is most simply defined as the ordinary practices of a culture, namely, coherent, meaningful, and purposeful activities (Brown, Collins, & Duguid, 1989). More specifically, an authentic learning task for students should have the following characteristics. It should: (1) cue the leaner to the desired solution(s) in order to promote "free exploration" or self-directed inquiry; (2) allow multiple solutions or solution paths; (3) have no explicit means for determining appropriate action; (4) be perceived as real or consequential by the learner to promote ownership of the problem; and (5) possess multiple criteria for evaluating solutions.

Problems or learning tasks that possess the above characteristics are known as ill-defined or ill-structured problems (Jonassen, 1997, 2000). In mathematics education, these learning tasks are sometimes referred to as "thought-revealing" or "model-eliciting" problems (Lesh, et al., 2000). In this genre of problems, the onus is placed on the student to create a model to capture in meaningful ways the complexity presented in the learning task. The central question for the task designer becomes, "Does the task put students in a situation where they recognize the need to develop a model for interpreting the givens, goals, and possible solution processes in a complex,

problem-solving situation? Or, does it ask them to produce only an answer to a question that was formulated by others?" (Lesh, et al., 2000, p. 609).

Problem-based learning (PBL) is one of the most extensive and elaborate instructional models in designing authentic learning tasks (Dabbagh, et al., 2000). PBL is defined as "the learning that results from the process of working toward the understanding or resolution of a problem" (Barrows & Tamblyn, 1980, p. 18). The learner is expected to actively participate in the learning process and construct his/her own knowledge through direct experience and interaction with the situation, that is, knowing-in-action (Schön, 1987). As Stepien and Gallagher (1993) state: "Problem-based learning is apprenticeship for real-life problem-solving" (p. 26). PBL problems are typically ill-structured and complex, revealing the underlying principles and concepts of a knowledge domain through descriptions of real life events and experiences, and serving as the stimulus and focus for student activity (Siegel et al., 2000; Norman & Schmidt, 1992; Stepien & Gallagher, 1993). PBL radically alters the role of the teacher from instructor to facilitator and as time goes on, learners become increasingly self-directed in the learning process (Shoffner & Dalton, 1997) by taking ownership of the problem and "assuming the roles of scientists, historians, doctors, or others who have a real stake in the proposed problem (Stepien & Gallagher, 1993)."

Hypermedia Support for PBL

The use of hypertext/hypermedia to represent PBL cases has been a primary interest to researchers of PBL due to its inherent non-linear interlinking ability in representing a complex and interconnected body of information (Hemstreet, 1997; Jacobson & Spiro, 1995). According to Hemstreet (1997), hypermedia can support the complexity of PBL environments by situating a complex problem in a story format and making additional information about the problem readily

available similar to how information is built into anchored instructional materials. Hemstreet adds that hypermedia can also provide a database of information where more information about the problem than necessary is included, and the organization of the information provides no hints about what is important or relevant to the problem. These hypermedia problem-representation capabilities support the characteristics of ill-structured problems and could provide an efficient and effective medium to design cases for learning environments that are problem-centered.

Additionally, hypermedia cases provide students with the capability of browsing the features of a case in a non-linear, multidimensional, semantic structure that mimics the brain's ability to store and retrieve information by referential links for quick and intuitive access (Keep & McLaughlin, 1995). This information seeking activity is designed to support an authentic process of inquiry consistent with problem-based pedagogy. It is a non-sequential activity that can be facilitated in a deliberate way by arranging information in a format within which exploration can take place. Developers, be they teachers or instructional designers, must chart out the knowledge students will "run into" in the course of working on a problem or case, and compare this to the stated goals of a course (Stepien et al., 1993). The question is however, how does one determine the degree and type of structure with which to arrange case information, and does it matter?

Sutyak et al. (1998) argue that case structure may have a profound impact on knowledge transfer and students' expectations of learning, and that case structure remains a fertile field of study. Additionally, Siegel et al. (2000) suggest that a high level of transfer might be attained through Web-based instructional design that supports case- and problem-based instruction and learning. Siegel et al. caution however that despite the powerful hypertext capabilities of the World Wide Web, many case-based designs continue to reflect a "traditional hierarchical

approach, modified by extended page-linking capabilities" (p. 2), inhibiting advanced knowledge acquisition and transfer.

Case Structure in Web-Based Hypermedia Learning Systems

In order to test the effects of case structure on problem-solving and knowledge transfer, this research project focused on hierarchical versus heterarchical Web-based hypermedia designs of ill-structured problems. Hierarchical hypermedia designs are linking structures (structures that facilitate navigation through a hypermedia system) that organize content into logical sections often by major topic area, resulting in several navigation levels with a top-down or tree-like structure (Oliver, 1996; Last, O'Donnell, & Kelly, 2001). Network-like or heterarchical structures are "more chaotic with random links jumping from one topic to another in a more referential fashion" (Oliver, 1996, p. 15). Typically, embedded links are sprawled throughout the content representing associations similar to knowledge representation in a memory model or network structure (i.e. rhizome-like). Hierarchical versus heterarchical hypermedia designs can also be viewed as a "depth versus breadth" topology of linking structures (Larson & Czerwinski, 1998). For example, in a hierarchical or tree-like hypermedia structure, the deeper a student browses the more detail about the topic is encountered, and in order to change themes (topics) the student must return to the highest level (Last et. al, 2001).

Although research indicates that a more tree-like or hierarchical structure limits navigational difficulties when browsing through a hypermedia learning system compared to a purely heterarchical structure, there is evidence that linking structures interact with learner characteristics (e.g. learners' prior knowledge and cognitive styles) and with the goal of the learning task (e.g. studying for an exam versus exploring or searching for specific information), and that the design characteristics of a hypermedia learning environment can enhance or limit

user performance and impact the quality of independent learning (Last et. al, 2001). To further explore the interaction between hypermedia linking structures and student learning and performance, particularly in a Web-based hypermedia learning environment, this research project addressed the following two research hypotheses:

1. In a heterarchical (rhizomatic, network-like) hypermedia design of an ill-structured problem, significant improvement in problem-solving schemes would be observed in students who regard learning as an active process of constructing meaning.
2. Students engaged in solving an ill-structured problem of heterarchical hypermedia design will demonstrate improved knowledge transfer compared to students engaged in solving an ill-structured problem of hierarchical (tree-like, topically organized) hypermedia design.

Method of Investigation

In order to empirically address the above research hypotheses, the first phase of this project is an *exploratory case study* to establish a set of assumptions that will guide future phases (Robson, 1993). This first phase serves as a diagnostic tool to study the nature of the independent variable (case structure) and the learning interactions, strategies, and exploratory pathways it generates in order to design an effective experimental study in future phases. Students' beliefs and perceptions about case structure were examined by engaging them in a Web-based, PBL environment to solve an ill-structured problem of hierarchical and heterarchical hypermedia design. The following research questions were addressed in this study:

1. How does exploration in the heterarchical hypermedia case compare to exploration in the hierarchical hypermedia case? Is one more comprehensive than the other? How many links did students visit? Were the links visited relevant or irrelevant to the case? How much

additional information was explored? How much time was spent on a page/link? How many links were revisited to gain more clarification of the case issues?

2. How does collaboration between group members in the heterarchical hypermedia case compare to collaboration in the hierarchical hypermedia case? Were students' decisions in terms of how to navigate the case content group-based or individually based? Were students' decisions on what actions to take while journeying through the hypermedia learning environment group-based or individually based?

3. How did students in each of the groups perceive the learning task in each of these case designs? Was the learning task perceived as authentic, challenging, complex, ill-structured, meaningful, relevant, and engaging? Were these perceptions different in each group?

4. How did students perceive the case structure in each of the groups? Did they find it difficult to navigate through the case? Why or why not? Did they find it difficult to locate specific information?

The ill-structured problem selected for this study is an Instructional Design (ID) case concerning the issue of "informed consent" prior to surgery. ID cases are archetypal examples of ill-structured problems (Jonassen, 1997) and have been selected as study materials due to the expertise of the researcher in this knowledge domain. The ID problem used in this research study relates to pre-operative instruction in which potential gall bladder disease patients learn enough about the surgical procedure to give 'informed' consent. The students are responsible for designing instruction and assessment that legally verifies that patients were fully informed. If such instruction could be validated as effective, huge benefits could accrue to the medical profession and certainly to the insurance companies given the impending number of malpractice

cases filed against physicians for either misinforming or *not* informing patients about possible risks of gall bladder surgery and/or alternative procedures to correct the disease.

The informed consent ID case described above was used in a previous research study (Dabbagh, et al., 2000) to argue that Instructional Design is a dynamic process of problem understanding and problem solution and that problem-based learning is an effective instructional method to teach Instructional Design because of its strategy for using problems as a stimulus for authentic activity and its emphasis on preparing learners to become lifelong critical thinkers. The case material was initially compiled in print form and presented to student groups in the Dabbagh et al. case study in a folder labeled by Barrows (1985) as the problem-based learning module (PBLM). The PBLM contained the problem statement, authentic malpractice court cases, samples of patients' medical histories, articles related to the problem of informed consent, samples of legal informed consent forms, and legal definitions of informed consent from Black's Law Dictionary. Students were also provided with related videos that demonstrated physicians explaining gall bladder disease and its treatment options and possible complications to patients.

The informed consent ID case has since been converted to a Web-based hypermedia design reflecting the two types of hypermedia linking structures discussed above: hierarchical and heterarchical. The hierarchical structure consists of an unmistakable and unique entry point to the case which begins with a narrative of the problem scenario and branches to a Web page with a menu of hyperlinks to six topically labeled case themes: legal cases, definitions, article summaries, legal forms, patient information, and perspectives of stakeholders in the informed consent issue. Each of these themes is further subdivided into sub-topics menus of hyperlinks reflecting a tree-like navigational structure requiring students to browse deeper into the linking structure for more case detail, and to return to higher levels in the hierarchical organization to

change themes and sub-topics. Navigation in the heterarchical structure on the other hand is enabled through embedded textual hyperlinks that embody the natural meaning of the narrative articulating the case information and relevant components. The hyperlinks are sprawled randomly across the case content representing referential associations that resemble a network-like or rhizomatic structure with no discernable hierarchy or repeatable paths. Furthermore, the heterarchical hypermedia structure describes the case issues and events in a story-like manner using real world simulations of characters and role-plays deepening perhaps the authenticity of the problem context. The story-like nature of the heterarchical linking structure will be considered an attribute of the heterarchical design and its implications on student perceptions of the learning task will be considered only to the extent to which students perceive it as an important or distinctive variable of the hypermedia learning environment.

Description of Study

Two groups of volunteer students in their last semester of study in a graduate program in Instructional Design at a large comprehensive university were assigned to explore the two case designs described above. The researcher initially sent an email request to fifteen students asking them to volunteer to participate in the study. Six students responded that they would be willing to participate (40% response rate). The first three who responded were assigned to the heterarchical case design and the last three were assigned to the hierarchical case design. Students were told that the study will take about three hours of their time and that they would each be given a $20 gift certificate from a major bookstore in the area to compensate for their time and effort. Each group of students was asked to come to a computer lab on a specific date and the students were given instructions on how to access the case. The group assigned to the heterarchical case design was identified as the *red group* and the group assigned to the hierarchical case was identified as

the *purple group*. Students in each group were instructed to use only one computer and select an operator amongst them (person sitting at the keyboard) who will be in charge of accessing the case online and clicking the mouse. The procedure for accessing the Web-based case required students to enter their group name, their individual names, and the operator's name. Then each group entered the URL corresponding to their case design assignment and the following instructions were displayed:

> This is an Instructional Design case study. Study the case and provide a one-page outline of your recommended solution in a Word document. While studying the case, you can highlight text, copy and paste portions of text, click images or links, print, etc. Every time you take an action, you will be asked *why* in a pop-up menu. Please be patient and answer as candidly as possible. You will not be judged or evaluated in anyway. This is a research experiment. When done, you will be asked to respond to a questionnaire to give us your suggestions. Thank you for participating in this study. Click on the arrow to enter the case.

Each student group was observed by the researcher while interacting with the case and their journeys through the hypermedia structure were tracked to a database (through a JAVA program) using a pop-up menu that automatically displayed when students used any navigation tool to move through the pages and links of the case and/or interact with the case content (e.g. clicked on a hyperlink, highlighted text, copied or pasted text, printed text, used browser navigation tools to move backward and forward, etc.). The pop-up menu requested short answers to embedded elaboration-seeking questions and required students to make selections from a list of choices to help determine: (1) whose decision was it to initiate the interaction with case content (group versus individual), and (2) why was that interaction selected (relevancy to problem-solving process). There were five options to choose from in the second question: (a) very helpful for case analysis; (b) somewhat helpful; (c) not sure, but decided to explore anyway; (d) didn't have any other option; (e) other reason (see figure 1).

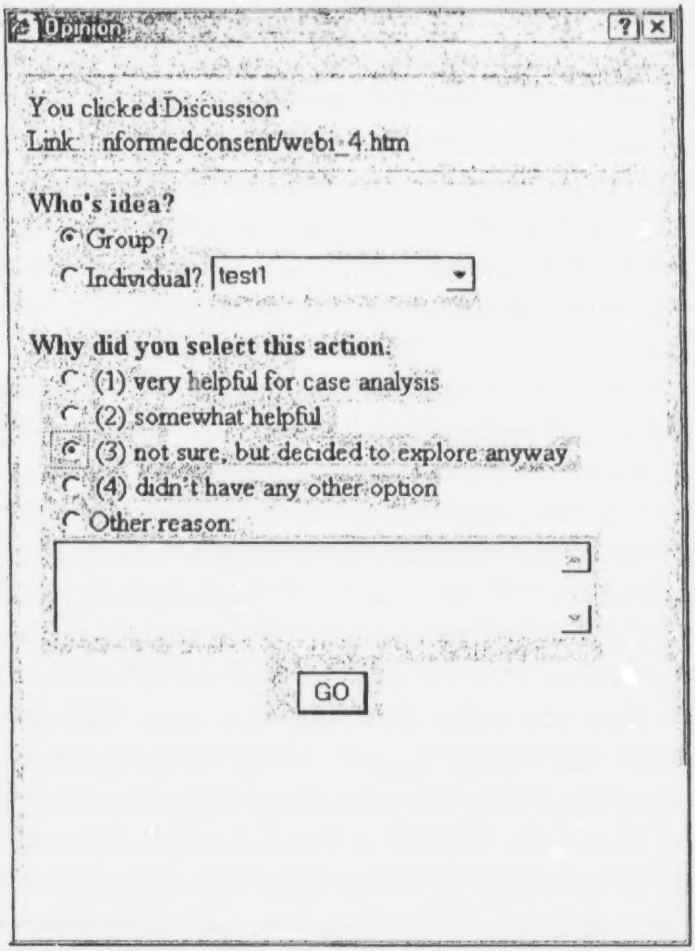

Figure 1: Pop-up menu displayed when interaction is initiated

A slightly different pop-up menu containing the options for question 2 was displayed when students exited the page that was visited, or completed the action that was selected, in order to determine whether students' initial perception about the usefulness or relevancy of the link/action to problem-solving was confirmed. This pre-post tracking technique was necessary to determine what students perceived as relevant and irrelevant case information. See figure 2.

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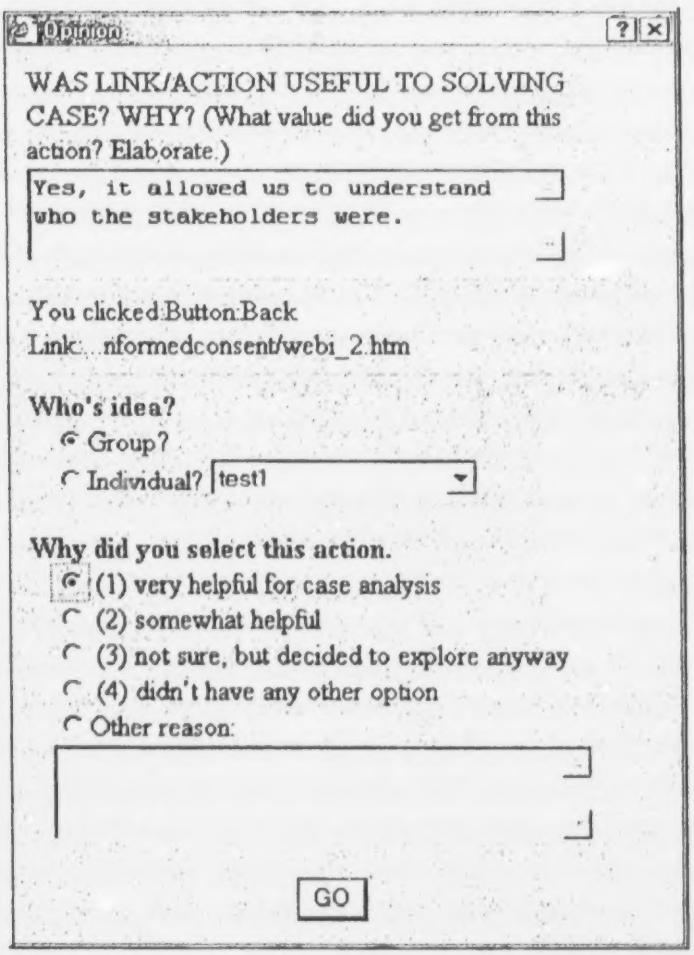
Option
WAS LINK/ACTION USEFUL TO SOLVING CASE? WHY? (What value did you get from this action? Elaborate.)
Yes, it allowed us to understand who the stakeholders were.
You clicked:Button:Back
Link:...nformedconsent/webi_2.htm
Who's idea?
Group?
Individual?
test1
Why did you select this action.
(1) very helpful for case analysis
(2) somewhat helpful
(3) not sure, but decided to explore anyway
(4) didn't have any other option
Other reason:
GO

Figure 2: Pop-up menu displayed after visiting link or completing action

In addition to the above information, the JAVA program recorded the URL of every page visited, the URL of every page in which an interaction was initiated, the start time of an interaction, the type of interaction, the time spent on every page/interaction, and the total session time. During each group session the researcher was silently observing the group processes and deliberations triggered while exploring the case content and taking notes. At the end of the session, each group submitted their outline of the case issues and recommended solution, and the

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researcher proceeded to interview each group and explained that during the interview group members may jump in and answer questions at any time. The interviews were audio recorded and later transcribed for further analyses. The interview questions were as follows:

1. What did you think of the case in general? Was it easy to understand? Complex? Ill-defined? Well-defined?
2. What did you think of the topic of informed consent? Was it realistic? Relevant? Meaningful? Was it a timely topic? Did it engage you in the case?
3. What did you think of the structure of the case? The way it was laid out? The navigation? The organization of the links and resources?
4. Was it easy to find what you were looking for?
5. Describe the general strategy you adopted when using the system or navigating through the case. In other words, did you have a plan of attack?
6. Do you think you had enough information to identify the main issues/problems to solve the case?
7. Do you think all of the information presented in this case was useful?
8. How would you change the case structure or present it differently?

Analysis and Discussion

This research investigation used a case study model. In addition to being an exploratory case study, this first phase is what Yin (1993, 1994) refers to as a *positivist case study model* where the researcher is attempting to establish the facts of the case by gathering evidence from a variety of resources and applying the concept of triangulation, which treats the evidence in a converging manner making any theory building inferences robust and viable. A qualitative approach was used to analyze the data. The primary data analysis techniques included content

analyses of the interview reports and descriptive statistics of the data collected from tracking students' journeys through the two Web-based hypermedia case designs. These two different analyses techniques support the concept of methodological triangulation in case study research (Denzin, 1978; Patton, 1990). The researcher's recorded observations and the groups' one-page outlines of the case issues and recommended solutions were used as data/source triangulation (Denzin, 1978; Patton, 1990) to cross check the accuracy of the data collected. Methodological and data/source triangulation ensure the credibility of this exploratory case study. In order to carefully organize and interpret the data using the above techniques, a data analysis matrix (see table 1) was developed that maps the four research questions of this case study to corresponding components of the primary data sources. Table 2 shows the descriptive statistics and findings from the JAVA tracking program, and table 3 shows the results of the interview that was conducted at the end of the study. A discussion of the data analyses and implications for each research question is presented below.

Research question 1: How does exploration in the heterarchical hypermedia case compare to exploration in the hierarchical hypermedia case? Is one more comprehensive than the other?

In terms of the breadth of exploration in the hypermedia cases the results showed that the purple group's journeys (hierarchical) were more comprehensive overall. The purple group visited 54% of the links compared to 41% for the red group (heterarchical). The number of links revisited by the purple group was also higher than those revisited by the red group (39% compared to 33%). Additionally, the number of unique links visited by the purple group was higher than the number of unique links visited by the red group (32% compared to 27%) (see table 1). However, the total time spent interacting with the case content was higher for the red group (2 hours and 40 minutes compared to 2 hours and 7 minutes). The red group spent an

average of 3.04 minutes on a page compared to 1.96 minutes for the purple group. This indicates that the heterarchical case structure may have caused the participants to reflect more meaningfully on the case content, studying and discussing the information more closely in order to formulate a problem solution that was appropriate. The data from the interview supports this finding. In response to interview question 6, the participants in the red group indicated that they "got immersed in the material" and had to "stop and look at what we had, and go step by step through what we learned and what we gathered to be able to reframe the issue".

On the issue of usefulness and relevancy of case information to problem-solving, the participants in the red group indicated that some of the information was not useful but that "only after looking at the information we were able to determine that it was not useful" and that "even the unuseful information was useful in helping us come up with a conclusion". The participants in the purple group pointed out that all the information was useful and that it was "good" information but did not elaborate on what information may have been more useful in helping them understand the issues of the case. The interview analyses indicated that the purple group seemed more focused on getting to information than on debating the issues and perspectives of the case content. The descriptive data indicated that both groups had the same percentage of links (55%) initially perceived, and later confirmed, useful, for understanding the case. However the red group had a higher percentage of links, 31%, initially perceived useful but later confirmed *not useful*, compared to 27% in the purple group. Additionally, the descriptive data indicated that the frequency reported for reason (c), "not sure but decided to explore anyway", was 29% for the red group compared to 14% for the purple group. These statistics indicate that the red group was more willing to explore links even if their initial perception was unclear about the usefulness of those links in furthering their understanding of the case issues. Consequently the heterarchical

case structure may have caused the participants to meaningfully reflect on the usefulness of the case content by exploring what may have been perceived as irrelevant information in order to appropriately frame the issues of the case.

The descriptive data also indicated that the purple group had a response rate of 20% compared to 11% for the red group on reason (a), "link perceived as very helpful for case analysis", and a response rate of 50% compared to 29% in the red group for reason (b), "link perceived as somewhat helpful". These two statistics imply that students interacting with the hierarchical case structure perceived more links as useful or helpful for case analysis than the group interacting with the heterarchical structure. However the nature of the hierarchical structure (i.e. the topical and layered-like organization of the links) necessitates that students "dig deeper" into the structure to find information, which could explain why exploration of the case was more comprehensive by the purple group. Interestingly though, the links that both groups found *very helpful for case analysis* (reason (a)) were very similar. Both groups found that malpractice cases, articles on informed consent and malpractice lawsuits, patient/physician interviews, and legal forms were very helpful in understanding the case issues (see table 1). This finding shows that both groups identified similar case information as useful but suggests possibly that the purple group may have been aided by the topical structure of the case design to identify relevant case information whereas the red group had to more carefully reason through the usefulness of the embedded links to identify relevant case information.

Research Question 2: How does collaboration between group members in the heterarchical hypermedia case compare to collaboration in the hierarchical hypermedia case?

In terms of collaboration between group members, the data from the computer tracking program showed that 97% of the decisions made by the red group were group-based compared to

86% in the purple group. This finding was also confirmed by the interview data. In response to interview question 5, the participants in the red group indicated that their strategy was "discussion mostly, sharing our perspectives, giving arguments for why this is important, and making decisions on which links to choose based on which one would help us figure out what informed consent was". The purple group did not seem to be as engaged collaboratively as the red group. In response to question 5, the participants in the purple group indicated that they "just wanted a summary … my mission was to get a summary, specific grasp on positions". There was no evidence in the interview data of the purple group of discussion on how to evaluate the usefulness of the case content in formulating problem issues (see table 3).

Research Question 3: How did students in each of the groups perceive the learning task in each of these case designs? Was the learning task perceived as authentic, challenging, complex, ill structured, meaningful, relevant, and engaging?

The interview data confirmed that both groups perceived the learning task (the case) as ill-defined, authentic, engaging and meaningful. In response to interview question 1, the red group indicated that the case was "very ill-structured" and "very authentic … when you think of an instructional design project, you walk in there and don't know the problem, don't know the resources, etc." and "in authentic cases even if you know some of those things, you don't have the opportunity to get those things in the order that you want" and "also some of the links provided information that wasn't helpful and that's real life". The purple group indicated that the case was "definitely ill-defined … it's up to the student to explore and find out what the problem is on their own" and "we didn't know what the problem was even after going through some of the links" and "it wasn't until after going through some links and gathering information that we tried to make a hypothesis as to what the problem was".

In response to interview question 2 (what did you think of the topic of informed consent), the red group commented that the topic of informed consent was very timely and engaging "because people are currently having problems with HMOs (Health Maintenance Organizations) and they are not well informed when they go to surgery". Similarly, the purple group commented that the topic was "engaging because at one point of our lives we are going to have to talk to doctors about possible surgeries and sign forms … so the topic was timely and relevant". See table 3 for more interview results supporting the findings for this research question.

Research Question 4: How did students perceive the case structure in each of the groups? Did they find it difficult to navigate through the case? Why or why not? Did they find it difficult to locate specific information?

In terms of case structure, the red group reported that the case was "structured very well" and suggested the addition of more pictures, audio, and video. The red group also reported that "there were major arteries (themes) in the case" that prompted a trail of exploration based on the story-like nature of the case content: "For example, on the administrative meeting page, we were introduced as instructional designers and then oh my god we have all these options, we could go to the office, the library, talk to Allen. That was a huge one, it revealed a lot of information." In response to interview question 4 (was it easy to find what you were looking for), the red group reported that it was not easy to locate information because "we didn't know what we were looking for and just like real life, this led us to have a lot of collaborative discussions … it was a matter of filtering out, and that filtering out prompted collaborative discussion". In response to interview question 8 (how would you change the case) the red group suggested leaving it as is except for the addition of more multimedia as mentioned above.

The purple group (hierarchical case structure) reported similar comments overall with some worthy-to-note variations. In response to interview question 4, the purple group reported that it was difficult to find information because they did not know what they were looking for. This was consistent with what the red group reported. In response to interview question 8, the participants in the purple group suggested (1) that hyperlink labels should be more contextualized and paraphrased to aid with the navigation; (2) that layers should be reduced; and (3) that information should be consolidated in the form of summaries at the first level of the hierarchical structure. In response to interview question 3, one participant in the purple group complained about the navigation: "my biggest beef was the navigation ... I felt that the information should have been consolidated ... it was very frustrating however the general structure was good". However the other two participants in the purple group described the hierarchical case structure as "fine" and added that they liked how "things were spread around" and "how the problem scenario was the first thing to read and then there was a second layer with the other case perspectives, etc.".

These findings suggest that the heterarchical case structure may have been more appealing overall than the hierarchical case structure due to its embedded and more contextualized (story-like) linking structure and non-layered organization. More specifically, the finding that one student in the hierarchical case design complained about having to go through layers in order to get to information confirms the structural differences in the two case designs and suggests that top-down linking structures may prevent students from making meaningful and well-reasoned choices about how to explore case content. It is important to note here that the student from the purple group who was frustrated with the layered design of the hierarchical case was the operator for the group.

Another interesting finding was that two of the students in the purple group commented that they would rather go through this case on their own and come together as a group afterwards to discuss issues. One participant felt that "this is an exploration thing" and that "a user should be able to go where they want to go at any time without being restricted or guided by others". The other participant added "this is a computer thing … I don't share computers well with others … that's why we all have our own computers". These comments further support why collaboration was not as strong in this group as it was in the red group.

The following is a summary of the results discussed above:

- Exploration in the hierarchical case design was found to be more comprehensive in terms of the number of links visited/revisited, number of unique links visited, and the total number of interactions generated, however, the average time spent on a page in the heterarchical case design was one and a half times the average time spent on a page in the hierarchical case design.
- Both groups identified the same links/pages as most useful with respect to relevancy to problem-solving suggesting that both hypermedia designs cued the learners to relevant case content, however, the group interacting with the heterarchical case perceived more links *initially* as useful and later determined that these links were *not* useful, which may imply that discriminating between relevant and irrelevant case information in a heterarchical design could be more difficult than in a hierarchical design.
- The heterarchical case design triggered more collaboration between group members than the hierarchical case design. The red group's strategy was clearly one of discussion and reasoning through the problem information.

- Perceptions of the ill-structuredness, authenticity, meaningfulness, and real-world relevance of the learning task were equal in both groups.
- Perceptions of case structure in terms of organization of links, resource information, and navigation, were overall more positive for the heterarchical case design with the exception of the comment about adding more multimedia elements to the case.

The two additional data sources (problem solutions and researcher's notes) confirmed the above findings but also revealed some inconsistencies that need to be addressed in future research designs. In terms of the problem solutions, which were in outline form, the red group indicated that the key issue was largely a communication problem between doctors and patients regarding informed consent and that there are no clear methods to evaluate that patients fully understand the risks and side effects of pre-operative and operative gall bladder surgery. Their recommended solution was that doctors need to inform patients "completely by providing resources and talking about all issues" and that patients should be given specific methods to obtain information and gain knowledge about "how to ask doctors questions and how to research their medical problem". The purple group was not as clear in their formulation of the case issues and problem solution. Although the group indicated that the case issue was largely one of communication between doctors and patients regarding informed consent, they did not suggest strategies on how to address this issue. Their focus was more on revising the actual forms of informed consent so that patients can understand better what they are consenting to.

Both groups did not clearly identify the Instructional Design issue, which was assessment of patients' knowledge about the risks and side effects of pre-operative and operative surgery. The case solution calls for the development of appropriate evaluation and assessment methods that guarantee patients' knowledge about the risks of surgery in order to minimize malpractice

litigations against doctors and hospitals. Additionally, the case solution should include the design of training procedures and instructional modules that ensure that doctors and/or hospital personnel are effectively communicating the necessary information to patients so that patients can make informed decisions. The development of instructional modules or information sessions for patients should also be recommended. It is important to note here that this research study did not emphasize or focus on the problem solutions. Its primary focus was on evaluating students' perceptions about hypermedia case designs of ill-structured problems and on tracking students' journeys and interactions with the case in order to study the nature of the independent variable, case structure. Important information was revealed that would help chart the course for the next research study.

The information revealed, particularly the additional time spent by the red group on the case, and the stronger collaboration demonstrated, justifies why their solution was perhaps more cogent than the other group's solution. There was however one inconsistency noted in the researcher's notes (and revealed in the tracking data as well) and that is that the purple group did not click on the "discussion link" which contained the actual problem question in the hierarchical case design. This may have impacted the problem solution of the purple group. This finding suggests that information in hierarchical design structures is more compartmentalized and prioritized according to layers and menu structures and could potentially lead to students' missing out on important case information unless it is clearly delineated. To add more confluence to this issue, the students in the purple group (hierarchical group) did not perceive the organization to be more isolated or layered. They noted that other than the problem scenario, which was the first link they visited, the other links in the topics sub-menus seemed to be of equal importance. This is an inconsistency that needs to be further addressed by enhancing the

design of the hierarchical case to ensure that students perceive it as a layered top-down structure and that they do not miss out on important case information.

Future Implications

This exploratory case study revealed important information about Web-based hypermedia case structure and its impact on student learning in a problem-based learning environment. Most importantly, it revealed that heterarchical case designs potentially increase student collaboration in a Web-based hypermedia design of an ill-structured problem and engage students in thinking critically about case content. More research however is needed to support and solidify these initial findings and to address the inconsistencies noted. The heterarchical versus hierarchical design needs to be further studied to ensure that depth versus breadth is the delineating factor and that irrelevant and relevant case content can be equally integrated in both case designs. Additionally, different student groups (e.g. low versus high prior knowledge) should be subjected to hypermedia case studies using several cases with varying structure (heterarchical versus hierarchical) and varying problem-contexts. Case analysis and solutions need to be evaluated by experts in the field in terms of their viability as a proposed solution. Evaluation criteria in future research will include answering questions such as "Was the problem solved?", "Can the learners articulate the causal relations implied by the solution?", "How cogent was their argument?", "Does it address all of the issues and constituents?", "Did the learners effectively reflect their own domain knowledge?", etc. (Jonassen, 1997, p. 86). The experts will be asked to rate their evaluations using such parameters on a Likert scale to quantify the problem solutions. Case analysis and solutions would need to be more comprehensive (i.e. not limited to a one page outline of case issues). Students will also be asked to respond in a written format to a list of questions after submitting their case analysis and solutions and will be individually interviewed

(instead of a group interview as was done in this study) in order to inter-rate participants' responses and determine response frequencies. The questions and interviews will address problem design issues, problem-solving issues, and group processes.

Since there will be multiple cases with varying structure and problem contexts in future research designs that identical and different groups of students will be interacting with, there will be two layers of data analysis, case-by-case analysis and cross-case analysis, affording a measure of knowledge transfer (identical groups interacting with different case-contexts). This type of research design is known as a *multiple-case study design* where the unit of analysis is a single case (Winegardner, 2001). In addition to being a multiple-case study design, the second phase will also involve a more defined experimental research design that will test the effect of case structure of ill-structured problems on complex problem-solving skills and knowledge transfer using several learning variables as predictors. This research will lead to the development of a design model that (1) supports the generation and Web-based hypermedia representation of ill-structured problem-solving tasks across multiple disciplines, and (2) ensures learning gains in complex problem-solving skills and knowledge transfer. Future findings will also inform, and possibly improve, assessment methodologies in educational research.

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Table 1: Relation of Research Questions to Primary Data Sources

Research Questions	Tracking Program Data Source	Interview Questions Data Source
(1) How does exploration in the heterarchical hypermedia case compare to exploration in the hierarchical hypermedia case? Is one more comprehensive than the other?	Number of links visited, number or links revisited, number of interactions initiated, time spent on each interaction, type of interaction, total session time, percentage of links perceived useful before and after visiting. Why was that interaction selected (relevancy to problem-solving process)? (a) Very helpful for case analysis? (b) Somewhat helpful? (c) Not sure, but decided to explore anyway? (d) Didn't have any other option? (e) Other reason?	Question 6: Do you think you had enough information to identify the main issues/problems to solve the case? Question 7: Do you think all of the information presented in this case was useful?
(2) How does collaboration between group members in the heterarchical hypermedia case compare to collaboration in the hierarchical hypermedia case?	Whose decision was it to initiate the interaction with case content (group versus individual)?	Question 5: Describe the general strategy you adopted when using the system or navigating through the case. In other words, did you have a plan of attack?
(3) How did students in each of the groups perceive the learning task in each of these case designs?		Question 1: What did you think of the case in general? Was it easy to understand? Complex? Ill-defined? Well-defined? Question 2: What did you think of the topic of informed consent? Was it realistic? Relevant? Meaningful? Was it a timely topic? Did it engage you in the case?
(4) How did students perceive the case structure in each of the groups?		Question 3: What did you think of the structure of the case? The way it was laid out? The navigation? The organization of the links and resources? Question 4: Was it easy to find what you were looking for? Question 8: How would you change the case structure or present it differently?

Table 2: Descriptive Statistics of Tracking Data

Tracking Program Data	**Red Group – Heterarchical Case Design**	**Purple Group – Hierarchical Case Design**
Time spent on case	2 hours and 40 minutes	2 hours and 7 minutes
Number of links visited	33 out of 81 (41%)	79 out of 146 (54%)
Number of revisited links	11 out of 33 (33%)	31 out of 79 (39%)
Number of unique links visited	22 out of a possible 81 (27%)	48 out of a possible 146 (32%)
Total number of interactions with the case (mouse clicks)	**34** - 33 links - 1 text selection	**84** - 79 links - 5 text selections
Average time spent on a page/link	3.04 minutes	1.96 minutes
Decisions made by group	33 out of 34 (97%)	72 out of 84 (86%)
Reason for interaction: (a) Very helpful for case analysis; (b) Somewhat helpful; (c) Not sure, but decided to explore anyway; (d) Didn't have any other option; (e) Other reason.	- (a) 3 times, 11% - (b) 8 times, 29% - (c) 8 times, 29% - (d) 4 times, 14% - (e) 5 times, 18%	- (a) 17 times, 20% - (b) 42 times, 50% - (c) 12 times, 14% - (d) 10 times, 12% - (e) 3 times, 4%
Percentage of links perceived useful for understanding the case and were actually useful	- 55%	- 55%
Percentage of links perceived useful for understanding the case but turned out not useful	- 31%	- 27%
Case links/pages found **very helpful**	• Cases page - contained the malpractice lawsuits filed by patients • Informed Consent Page - contained the definitions of informed consent • Research Page - contained links to information about the history of informed consent, articles pertaining to the issue of informed consent and malpractice lawsuits, and sample statements filed with a hospital regarding claims • *Group was unable to access audio interviews*	• Cases page - contained the malpractice lawsuits filed by patients • Articles page - contained articles from scholarly journals about malpractice issues of informed consent • Interviews page - contained interviews with doctors, medical staff and patients about informed consent • Legal Forms - contained sample forms required by the US dept. of health and hospitals for informed consent • *Group did not access discussion page link*

Table 3: Interview Results

Interview Question	Red Group - Heterarchical Case Design	Purple Group – Hierarchical Case Design
(1) What did you think of the case in general? (easy to understand, complex, ill-defined, well-defined)	Cecilia – definitely very ill-structured Beth – Very authentic when you think of an instructional design project, you walk in there and don't know the problem, don't know resources, etc. Kathy – In ill-structured and authentic cases even if you know some of those things that you want, you don't have the opportunity to get those things in the order you want, person's not available, emails not available, etc. Also, some of the links provided information that wasn't helpful and that's real life.	Dana - I thought it was ill defined, cause at first we didn't know what the problem was, and even after going through some of the links we still didn't have an idea of what the problem was that we were trying to solve. It wasn't until after going through some links and gathering information that we tried to make a hypothesis as to what the problem was. Claire - Agree it was ill-defined, had a grasp of the informed consent issue from the initial problem statement, but I know there was something there that we missed, I have a feeling there were links we should've clicked on rather than what we did. Frankie – definitely ill-defined, it's up to the student to explore and find out what the problem is on their own and which is a good thing.
(2) What did you think of the topic (informed consent)?	Kathy - Very timely because in times of engaging society and time in the medical age and HMOs, people having problems and not being informed Cecilia - That applies to a real world example, my father goes to surgery quite a bit and he comes back with options and we grill him about pros and cons, who knows what he was told, did you sign a form	Frankie - Engaging to me cause at one point in our lives we are going to have to talk to doctors about our own health and possible surgeries we may have, so I think its relevant to almost anybody and easy to understand. I had a narrow perspective of what informed consent was but after going through the case study I can see how it can be applied in different situations. Dana – very relevant for us cause we all will need to go to the doctors and sign the forms. It was good to see disparity of information that is provided to some patients, might be able to see that you're going to a doctor who is not providing you with all the right information, so you need to find another doctor. Claire - Thought it was timely and relevant.
(3) What did you think of the structure of the case? (well structured, ill-structured)	Kathy - Think it was structured very well. I liked it cause it made it an ill structured problem. I wouldn't put more structure to it, perhaps less text, some audio, more multimedia, got tired of reading the text even though I needed to get through it, might've been other ways to present some of the material. I'm thinking images, audio clips, or movie clips might've made it more interesting. Cecilia -There were major arteries and you have a couple of options off of it so we follow those trails to the end and then	Claire - My biggest beef was the navigation. We went to patient information first to get that perspective, question 1 then back, question 2 then back, felt that the information should've been consolidated, or a previous and next link. It was very frustrating. However the general structure was good. I'm wondering if there might've been something more obvious. I liked how the problem scenario at the top was the first thing to read, having a second layer with a patient, doctor, hospital administrator, insurance and have all of those views there

	had to go back. For example, on the administrative meeting page, we were introduced as Instructional designers and then oh my god we have all these options, we could go to the office, the library, talk to Allen. That was a huge one, it revealed a lot of information.	and have supplemental information under those. So could make more apples to oranges comparison. Frankie – I thought the structure was fine. Things were spread around and it wasn't a linear thing, visit this first, second, third, which may be frustrating to some users. You didn't have to give much thought to where things were. Dana – I agree it wasn't linear but there was a theme around all the topics but didn't know what it was until you went into the links. The only link that I didn't know how it tied was the videos. Didn't know how the video of the gallbladder tied in.
(4) Was it easy to find what you were looking for?	Kathy - Not really, we didn't know what we were looking for. It wasn't like every link gave us an "ah hah" moment. Just like real life, that's what led us to have a lot of collaborative discussions and different perspective like 'this is not ~~fulfill~~, etc.was a matter of filtering out and that filtering out that prompted collaborative discussion	Frankie - Only when we knew what were looking for, then we knew to go back to it for different things, but it wasn't at the main menu, only when you visited that place before. Dana - I agree, kind of didn't know what type of information you were going to get, for example when you went to patient information you got survey questions given to patients.
(5) Describe your general strategy while using the system.	Kathy – Discussion mostly, sharing our perspectives, giving arguments for why this is important. My strategy was to gather as much information as possible, information that has something to do with informed consent, patient, and gallbladder. I would like to look at as many links as possible. Making decisions on which links to choose based on which one would help us figure out what informed consent was.	Clare - Just wanted to get a summary, I knew there were players, my mission was to get a summary, specific grasp on the positions, we found that information was too specific so we went on a hunt for general information and that led us to legal information. So this was good.
(6) Do you think you had enough information to identify the main issues/problems in the case or to solve the case?	Kathy -Yes I think, I was glad that we stopped when we did, I had to pull myself back and reflect on what we looked cause you got so immersed in all the materials, had to stop and look at what we had but I felt good we had a definition of what informed consent was. Cecilia - I think so cause towards the end we had got to the point where we were thinking is this really a problem of informed consent or of the doctors, … it wasn't a problem of the signing of the forms, it was of the doctors communicating to patients, and the patients educating themselves and being guided toward resources. Beth – At the end we were able to frame it better. It took to the end for us to realize that. We had to step back and go step by step what we learned, what we gathered, and realize that wasn't really what the	Frankie - I think we had enough information to identify the main issues but because it's an ill-defined problem there is no 1 solution, so I don't know if you'll ever solve the problem, you may get an idea on perspectives, come up with guesses or ideas. Clare - Got a good grasp on the informed consent problem, got the sense there is a specific gall bladder case that had an informed consent issue bent around it and that was just illustrative of this bigger issue, that we didn't get to if it does exist.

	problem was and reframe it. It was more a communication issue.	
(7) Do you think the information was useful?	Ceclia - some of the information was not useful, example the severity, we never went there…so it's not clear. Like the diagnosis, it confirmed what the doctor said but it didn't really help us. In the end, all information helped me come up with a conclusion, even the unuseful information was useful. This is the context of the authentic environment. Only when looking at the information after we had come up with a conclusion, we could say that this part wasn't extremely important, but not before.	Frankie - I think it was very useful at getting the different perspectives for the problem of informed consent specifically the articles, had scholarly articles, then miss magazine gives you down to earth perspective, in that sense that was good information. Dana - Information was useful, with the legal cases you would click on the case and it would bring up that information. Clare - We questioned the legal cases, woman's son was suing the doctor cause medication caused pancreas disease, never mentioned if doctor warned her, needed more information about informed consent here. Survey questions and answers, particularly patient questions and answers seemed too detailed. A summary would've been better.
(8) How would you change the case or present it differently to students?	Beth - more multimedia, pictures, sounds, something to pull them in, graphics. Cecilia - I would leave it as it is. If its objective is to be problem based, authentic ill structured environment then leave it as it is … the group was beneficial, collaboration was key, if I had to do this individually, I would've gone on with my informed consent focus and been less likely to look at other links that Beth suggested. Maybe we had arguments about where to go, what does that mean, but this keeps you on task when you're with others and helps you flesh out detail and question things and not jump on the first link that you see. If no one is there to hold you back then you're just going to click, click, and click. If there is a group someone says something.	Dana - Label the links differently, be more specific, instead of 'question1', paraphrase the question that is asked so person knows where they are going and whether information will be useful, instead of going through layers and layers and finding information wasn't useful. Clare - I agree, descriptions so we know what we're getting into. Consolidating information so there are summaries. Brief summaries of legal cases, went to abstract, history…help bring that information to the first level so you don't have to click back again. Frankie - I would prefer to go through this case on my own and come together afterwards to discuss issues. I think as we were going through we discussed where to go but I don't think we collaborated on the issue in general of informed consent. In an exploration thing, I think a user should be able to go where they want to go at any time. Clare - I agree with Frankie. I don't share computers well with others. Maybe it's a computer thing. That's why we all have our own computers.

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